# Design and Fabrication of Bidirectional Electronic Driven Wheelchair

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**Abstract**
*Locomotion is a problem for the disabled the world over. The use of manual wheel-chairs, which are common in developing countries can result in inflicted shoulder pains, stresses on internal organs and cardiac problems. The electronically driven wheelchair (EDW) that are available in developed nations provides succor for this class of people. However, this technology is not available in developing countries. This work was carried-out to domesticate this technology to make it available for investors involvement and ultimately affordable to cater for the growing population of the disabled in Nigeria. The EDW was fabricated using two rear wheel motors, two 12V DC deep cycle batteries, a solar panel module to enhance the batteries performance for outdoor usage, frames made from galvanized steel and a control module. The EDW has a joystick for control of bidirectional movement. It has an additional advantage that the batteries can also be charged with a 220V AC source. The cost of materials and components fabrication of this EDW is N99,900. The performance of the first version of EDW in the tested environment showed that the technology can be localized with further improvement in its radial motion.*

***Keywords:*** *Electronically driven wheelchair, bidirectional motion, low-cost, disabled, mentally competent.*

## 1.0 INTRODUCTION

Nigeria with a population of over 170 million, has an estimated figure of 8 million disabled using wheelchair (WC) and crotches (Bureau of Public Health, 2015). The electronic driven or motorized wheelchairs are prescribed for persons who cannot propel a wheelchair with their hands or feet or who have a medical condition or other reasons that contra-indicate the energy expenditure associated with such exertion. The motorized WC would not normally be prescribed for patient with minor or temporary disability, Ragnarsson (1992), but for those with severe neuro-musculoskeletal disabilities or poor endurance due to cardiopulmonary diseases (Lucas *et al.,* 1997). Some use the motorized WC only in rare situations, such as to travel long distances, while ambulating or propelling a manual WC for shorter distances within home environments. The prospective user must be mentally competent and observant, have adequate sitting balance and adequate vision. Coordination and strength of some muscle groups in the upper extremities, neck or face, is required to operate the WC control mechanism. However, there are special control systems for individuals with poor hand/arm functioning. For instance, people with cerebral palsy have great difficulty coordinating their hand/arm movements. EDWs appear to be evolving faster than manual WCs (Al-Rousan and Assaleh, 2009; Al-Haddad *et al.,* 2012). Increased computing power, low cost microcontrollers, and a greater variety of sensors have produced complex interaction between EDW and their users (Cooper, 1999; Rini *et al.,* 2011; Lonttis and Struijk, 2012).

Motorized WCs no longer consist of manual WCs fitted with two drive motors but well-articulated complex mechanical structure with purpose driven semi-automated subunits. There is wide array of models available to consumers namely; rear-wheel, mid-wheel, and front-wheel driven WCs. Certain types can climb stairs and even cluster over obstacles (Bagum *et al.,* 2012; Quaglia *et al.,* 2011). With so many models and features available, users should consider safety and performance characteristics of electric powered WCs when deciding type of device to select. Ideally before any WC will be prescribed for the disabled in Nigeria, some factors will be considered namely: the principal WC features and options based on individual's characteristics and needs (Ismaila *et al.,* 2013). To avoid unnecessary cost, the prescribed WC should have only those optional features that are useful and necessary to achieve optimal functioning. The WC must fit the user properly to make for comfort, provide maximum mechanical advantage and energy efficiency, and to prevent medical complications (Paquet and Feathers, 2004). Incorrect fitness may result in poor posture, joint deformities, restriction of joint movement and general mobility, pressure sores, circulatory impairment, and actual pain (Cheng-Lung, 2007).

There are many kinds of motorized WCs in the market that to select appropriate one can be difficult. However, finding the right EDW can make all the difference to a person's life and independence (Mohan *et al.,* 2012). There are many reasons for deciding to use an EDW over other types since pushing a manual WC would require a lot of human energy to operate. Using an EDW takes less physical effort and, due to its increased weight and stability it is safer than the manual WC in steeper terrain. Sometimes a care giver is not physically able to push a person in manual WC when navigating rough surfaces and uphill. The EDW with the motorized controller mounted at the rear (i.e. attendant control), however, takes off stress from caregiver/patient (Iyonmahan, 2014).

Electronic driven WCs generally have two 12V batteries, two motors mostly with gears that projects the wheels on either side, a controller that determines the direction of movement, and some embedded with speed control buttons to moderate the speed of the vehicle. Most motorized WCs have standard features namely: a frame (fixed or adjustable), seating upholstery, armrests and footrests (Akmeliawati *et al.,* 2011; Anirudh and Satpathy, 2014). Smaller, more basic powered WCs are available with folding frames, which may be useful for safekeeping or transportation. Motorized WCs come with either on-board or off-board charger that replenishes the batteries. The advantage of an on-board charger is that you do not have to remember it when travelling. Batteries are rated in ampere-hours (AH) and this will, in combination with the efficiency of the motor, determine the distance the WC can travel constantly before requiring recharging.

Several works have been carried out on development of EDWs for physically challenged persons. Chelliah *et al.* (2016) presented the design and development of cost-effective motorized WC. This motorized WC has a single geared motor that is used to transmit power to the rear wheels. This special feature reduces the cost and weight of the WC. An Ergonomic front wheel steering mechanism was designed and developed to turn the WC left and right. The conceptual design was validated by developing individual parts in Solidworks. The front wheel steering mechanism is analyzed using ANSYS and the values obtained were compared with theoretical calculations. From the computational and theoretical results, it could be observed that the theoretical calculation matched well with computational results. Even though the concept showed that a manual C can be converted into low cost Motorized WC, there are limitations to which type of manual WCs can be converted.

Rokonuzzaman *et al*. (2011) designed an autonomous mobile WC for disabled using electrooculogram (EOG) Signals. The showed the implementation of a simple, effective and low-cost design of a microcontroller-based WC using the EOG signal collected from muscles that are responsible for the movement of the human eye. This was simply an exploratory research that was carried out to enable disabled person control the WC using movement of the eyes. Electrooculography (EOG) is a technique for sensing and recording the activation signal of the muscles and it can be used to collect and evaluate the myoelectric signal generated by the eye muscles during different movements. Kim *et al.* (2011), published a paper on design and control of a WC robot for handicapped or elderly persons. Novel multi-functional design concepts were introduced. The first function was to balance the chair always parallel to the flat ground so that the driver feels comfortable when driving on the slope. The second function was to help the driver to stand up by pushing the chair so that the driver can get out from the chair with ease. The third design was to make it foldable for ease of transportation for automobiles, and the last function was an immediate stop and start protection. Experimental studies were conducted to demonstrate the feasibility and functionality of each mechanical design, but it largely remains at concept level.

Begum *et al.* (2012) carried out research on design of an automated WC with stair crossing facility. The key objective was to find an easier way to cross inclined stairs with the modality. A new phenomenon was found from engineering analysis to cross stairs in an efficient way by the proper selection of wheel radius. The developed “Automatic WC” was aimed at providing comfortable and dynamic life-style for the handicapped. The main drawback of the WC was its high cost. Kaur and Vashist (2013) dwelt on automation of WC using Mems accelerometer (Adxl330). The automated system to control the motor rotation of the WC was based on head and hand movements of physically challenged persons. To facilitate this, an accelerometer device (ADXL330) based transmitter is fitted either on user’s head or hand. Based on the head or hand movements the transmitter generates command signals that is received by a receiver fitted on the back of the chair. This receiver in turns drives the motor fitted to the WC. The ADXL330 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs, all on a single monolithic IC. The WC can be driven in any of the four directions i.e. left, right, forward, back based on simple electronic control system and the mechanical arrangement that is controlled by an Atmel 80s52 microcontroller. The limitations were that the device was not fully tested and there was no power optimization.

The aim of this study is to evolve local technology in the design and fabrication of EDW suitable for the disable and worth investing into by entrepreneurs. In this first version, cost and time of producing a unit of the system, and aesthetics were not paramount issue for considerations in the design.

## 2.0 MATERIALS AND METHOD

The following materials have been used for the construction of the EDW: two 12V DC 18AH deep cycle batteries, a geared 12V motor, a PIC16f876A microcontroller, an 8-digit liquid-crystal display (LCD) unit, 2828 pin enhanced flash/eeprom, a 60W solar panel, a 220V AC; 12V DC inverter, a joystick, a 220VAC step down transformer TR1, a bridge rectifier BR1, a RL5 relay, a D12 diode, a Q1 transistor and a X1crystal. The system architecture is shown in Figure 1.

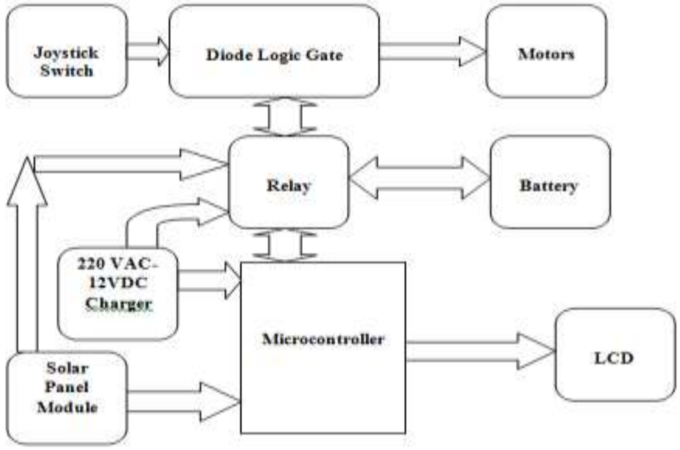


**Figure 1: Architecture of the Electronic Driven Wheelchair**

Figure 2 is the circuit diagram for the device. The joystick part contains push buttons switch, one for each direction. When it is pressed forward, it sends voltage through the diode to the relays to activate both motors in the forward direction that is clockwise motion. When you release the button, it deactivates the motor to a stop position acting as a braking system. If the reverse button is pushed it sends signal to the relay through the diode to activate the motor in anticlockwise direction, thereby reversing the wheelchair. The charging part contains a 220VAC step down transformer TR1, which steps down the 220V AC to 12V AC while a bridge rectifier BR1 converts it from 12V AC to 12 VDC, which is used to charge the battery. Relay RL5 is used to control the charging, which stops charging when battery is fully charged. Diode D12 allows the flow of voltage from solar panel in one direction into the battery by the microcontroller and the relay RL5 allows charging from solar panel to be activated. The microcontroller reads the voltage level of the battery and solar panel; if the battery is fully charged it will send a high logic to transistor Q1, which activates the transistor and the relay to deactivate the charging from either the 220V AC charger or solar panel. The LCD displays the readings of the microcontroller while crystal X1 is used to generate the operating frequency for the microcontroller activity as a timing circuit.

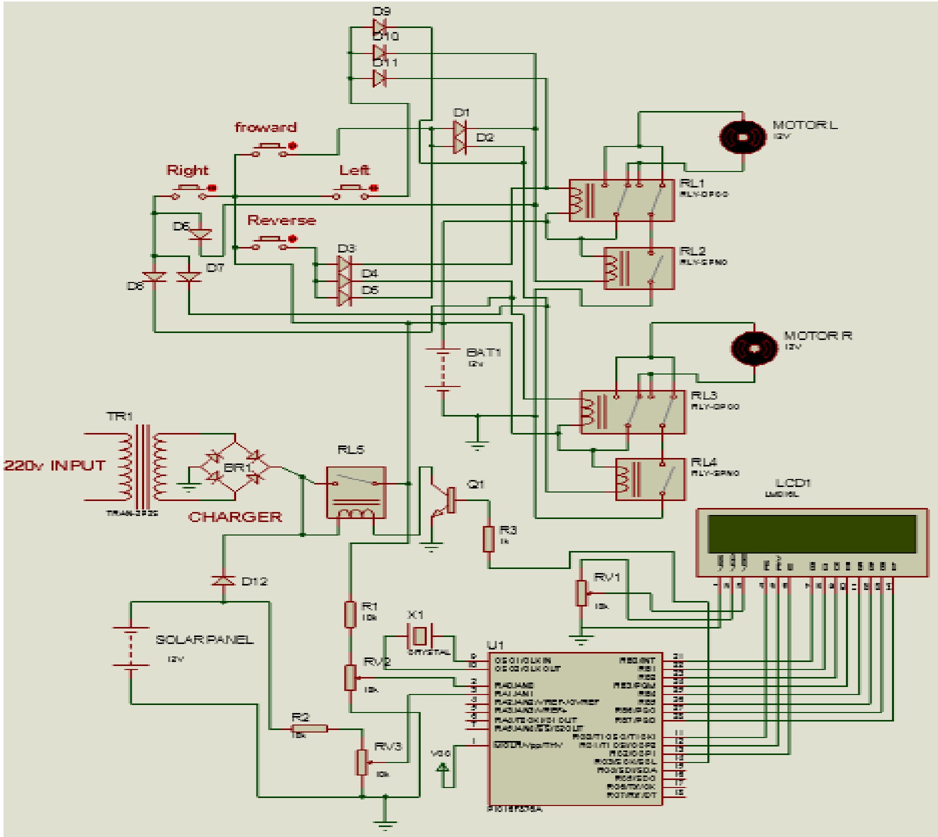


**Figure 2: Complete Circuit Diagram of EDW**

In the design and fabrication of a unit WC, the hand tools used include: cutter, hammer, mallet, screwdrivers, files, T-square, hacksaw, electric welding machine, electrodes, welding nozzle, vice and marker. And the process of using these hand tools does not at any time require more than two personnel. Time lag to produce each component of the wheelchair was not accounted for as it was not part of the primary objectives of the study.

### 3.1 Implementation of Design Process

The structure of the EDW was designed using AUTOCAD software to produce Figures 3(a) and (b), and 4(a) and (b). Figure 3 shows the right side and front side elevation of the vehicle. In this design the length of the arm rest was designed to be 350 mM which follows ergonometric design standards for wheel chair users (Paquet and Feathers, 2004).

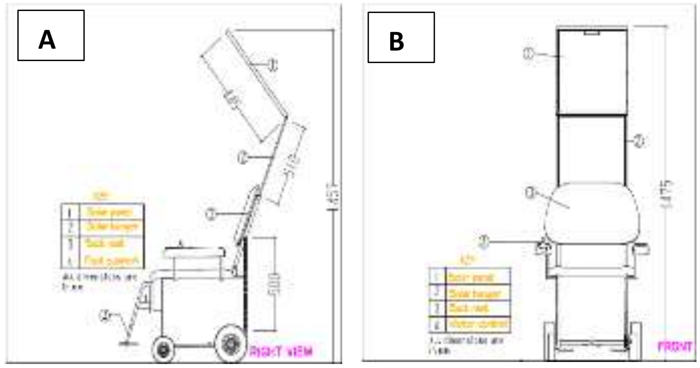


**Figure 3: (a) Right Elevations of EDW, (b) Front Elevations of EDW**

Figure 4 shows the left side and rear side elevations with the angle of the back rest, as 109$^{o}$ for ergonometric wheelchair users (Paquet and Feathers, 2004).

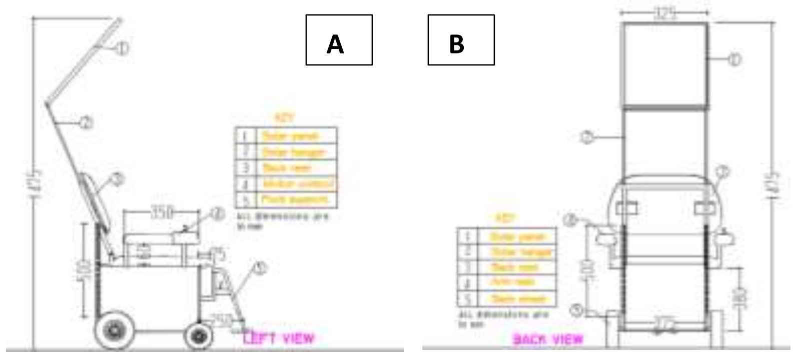


**Figure 4: (a) Left Elevations of EDW, (b) Back Elevations of EDW**

### 3.2 The Fabrication Process

The motorized WC was fabricated at the Faculty of Engineering main workshop using galvanized steel and stainless steel pipes with gauge 8 mild steel and stainless steel electrodes respectively. There is a base support as shown in Figure 5 with the base frame; and the tires are designed to provide support for the electric motors and battery. The geared motors were connected to the tires through two inches bearing welded below the frame.

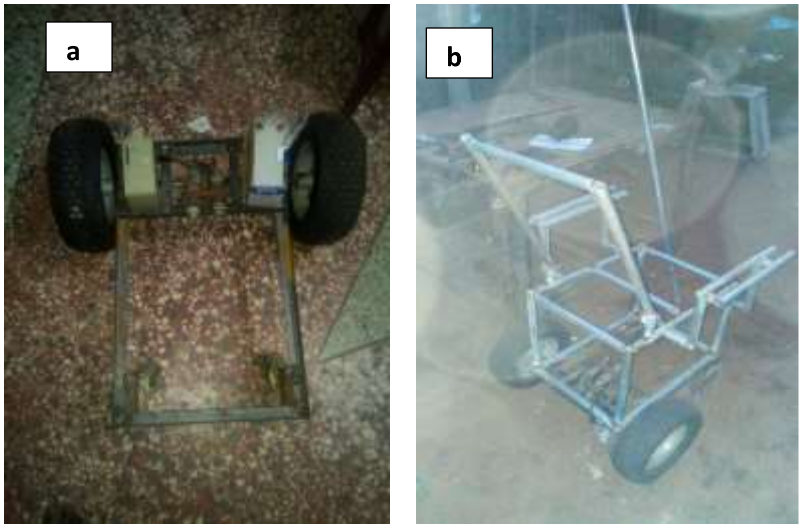


**Figure 5: (a) Base of EDW, (b) Skeletal Structure of the EDW**

The fabrication of the seat base was done using three-quarter galvanized steel pipes welded together on the base support. The dimension of the base followed the design specifications in Table 1. The arm rest was also fabricated using galvanized steel pipes, while given considerable seat depth as in ergonometric studies (Paquet and Feathers, 2004), to allow for comfortable sitting of the user. The back-rest skeleton shown in Figure 6 was fabricated using galvanized steel pipes. The back rest was attached to the seat base by a hinge joint to allow for angular extension.

**Table 1.** Wheelchair Specifications

| | |
|---|---|
| Weight capacity | 120 kg |
| Weight | 20 kg |
| Seat width | 458 mm |
| Seat height | 500 mm |
| Arm height from seat | 160 mm |
| Arm length | 350 mm |
| Back height from seat | 590 mm |
| Panel Height | 445 mm |
| Panel width | 325 mm |
| Front wheel radius | 60 mm |
| Rear wheel radius | 100 mm |
| Overall height | 1475 mm |
| Overall width | 547.7 mm |
| Upholstery | Fabric |

## 3.0 RESULTS AND DISCUSSION

The finished product of our design and fabrication processes are as displayed in Figures 6 and 7. The left and right views of the EDW are as shown in Figures 6(a) and (b) respectively, while Figures 7(a) and (b) show the rear and front views of the vehicle respectively. The prototype EDW is powered by two 12V DC and 18 AH deep cycle rechargeable batteries connected in parallel to produce an output of 36 AH and 12V DC. The battery is charged by a 220 V AC – 12V DC charger circuit embedded in the main circuit. In this prototype, two 12V DC geared motor provide the driving force, which draws a current of 1.1 A at optimum performance and a current of 5 A from resting position. The programmable microcontroller controls the entire processes. A PIC16f876A microchip device was used because of its low power consumption, expanded memory space and simple programming instructions. The microcontroller reads the battery level and converts it to readable value, which is sent to the LCD display. The LCD display guides usage, providing first-hand information about energy level of the batteries. To replenish the batteries, electricity from the mains cater for that purpose. However, when weather is favorable, solar system ensures reliable energy supply to the vehicle while replenishing the batteries simultaneously. The microcontroller consists of a 28-pin enhanced flash/eeprom and the 8-bits LCD units for monitoring. The solar panel module used has 60 W power rating and it also serves as a backup charger that replenishes the two 12V DC batteries when the wheelchair is in used for outdoor purposes. The solar panel module is attached as a roof above the WC for optimum exposure to sunlight. The battery is charged either by a 220 V AC; 12V DC charger or by the solar panel module controlled by the PIC microcontroller, which also acts as an interface that displays battery power level on the LCD and disconnect the charging circuit if battery is fully charged. The inner chamber was covered with galvanized steel nets to allow for cross ventilation in the inner chamber, and to reduce the weight of the WC. The panel for external charging system has also been equipped with a switch. The adaptor for the alternating current charging module for the EDW is situated on the right side of the WC. The housing for the relays and circuitry system is attached to the back covering of the inner chamber.

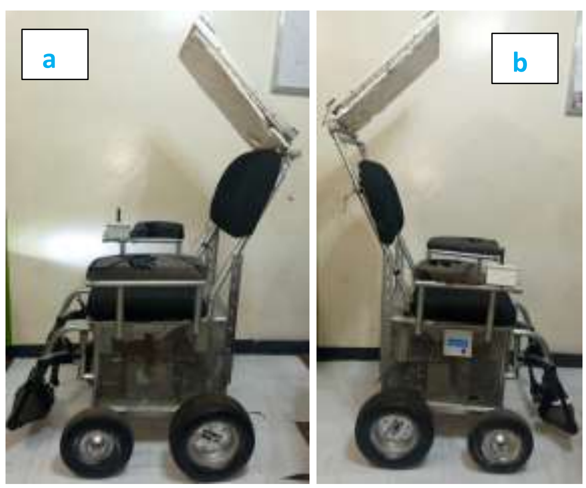


**Figure 6: (a) Left View of the Finished EDW (b) Right View of the Finished EDW with solar PVC roof**

On the right-side view of the motorized WC, is where the LCD is fixed and it displays the voltage of the battery and charging information of the solar system.


**Figure 7: Rear View (a) and Front View (b) of the Finished EDW with solar PVC roof**

A sealed plastic material to prevent water from affecting the circuits was used; while the foot rest used is a detachable simple lever system. The foot rest length is extensible depending on the length of the leg of the wheelchair user. It is also embedded with a belt that serves as support for the WC user. The summary of results obtained from the energy consumption pattern of the EDW are as interpreted in graphical form in Figures 8 to 10.

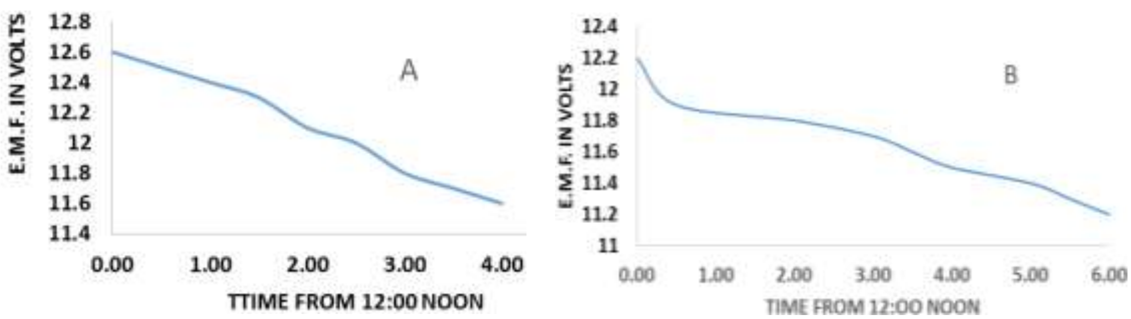


**Figure 8: Battery capacity dissipation against running time**

Figure 8 shows the power dissipation characteristics of the EDW. From the graph, the WC dissipates 30WH on the average every hour when used continuously.

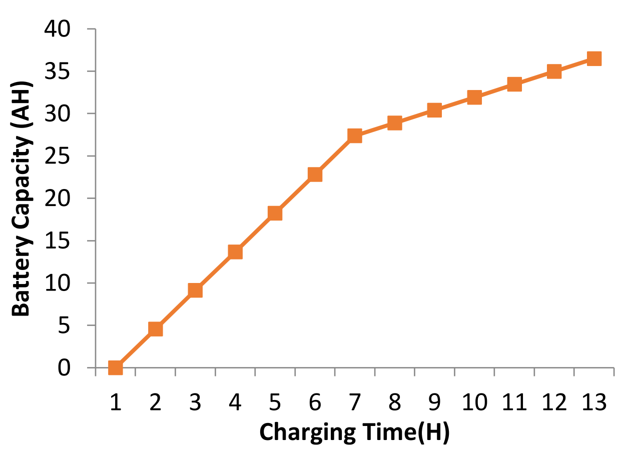

**Figure 9: Battery Capacity against Charging Time Using Solar**

Figure 9 illustrates the rate of charging of the power bank (i.e. the battery) measured in Watt-hour against Time (in hours) using the solar panel. From the Figure, it takes 11.8 hours to fully charge the batteries when the solar system is activated. In Figure 10, however, it takes only 4 hours, 24 minutes to charge the power bank using the mains.

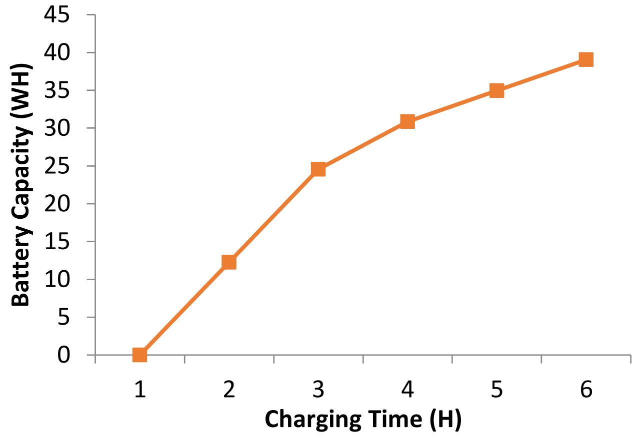


**Figure 10: Battery Capacity against Charging Time using Mains**

## 4.1 COST ANALYSIS

The run-down of the cost analysis for the design and fabrication of the WC is shown in Table 2 and prices of EDW in local currency is shown in Table 3. And all the materials are sourced in Nigerian market.

**Table 2:** Cost Analysis for Design and Fabrication of EDW.

| Component | Quantity | Unit Price(N) | Amount(N) |
|---|---|---|---|
| 3/4" Galvanized pipe (1800 mm) | 2 | 2500 | 5000.00 |
| Angle bar (1200 mm) | 0.5 | 1500 | 1500.00 |
| Galvanized metal net ($1^2$m) | 1 | 400 | 400.00 |
| 12V DC deep cycle battery | 2 | 7000 | 14000.00 |
| DC motors 12V | 2 | 14000 | 28000.00 |
| 60W Solar Panel | 1 | 15000 | 15000.00 |
| Joy stick control | 1 | 5000 | 5000.00 |
| Electrical Components | | 5000 | 5000.00 |
| 8 Digit LCD Unit | 1 | 3000 | 3000.00 |
| Back Tire | 2 | 2000 | 4000.00 |
| Front Tire | 2 | 1500 | 3000.00 |
| Cost of Labour (Welding) | | 5000 | 5000.00 |
| Seat Materials | 2 | 1000 | 2000.00 |
| Foot Rest | 2 | 2000 | 4000.00 |
| Transport | | 5000 | 5000.00 |
| | **Total** | | **99,900.00** |

**Table 3:** Prices of existing wheel chair models available in the market.

| S. No | Wheelchair Models | Price (N) |
|---|---|---|
| 1. | FS110A | 377,000 |
| 2. | FS101A | 400,000 |
| 3. | FS108LA | 526,000 |

Compared to the existing motorized wheelchair models, the motorized wheelchair designed by this study has up to 75% cost saving as it is made from locally available materials. However, performance and aesthetics are inferior to the existing EDW. The total cost breakdown amounts to Ninety-Nine Thousand Naira (N99,900.00) only, which is about 25% of the average cost of an imported electric driven wheelchairs. The huge cost differential arises from our ability to source materials needed for the EDW locally but excludes the cost of tuning module. However, when completed the modality is expected to be cheaper than imported ones bringing about corresponding savings from foreign exchange transactions including shipping cost. The development of the machine is at incubation stage. All other tests for commercialization would have been carried out for validation/efficiency before commercial production. The issues relating to sideways control of WC movements cannot be overemphasized. It is the aspect of control of EDW that incapacitated the much-desired freedom (Al-Haddad *et al.,* 2012; Al-Rousan and Assaleh, 2009; Bagum *et al.,* 2012). In future study, the electroencephalogram (EEG) unit will be incorporated into the system to enable smart control mechanism for the modality. A smart EDW will accommodate usage by physically incapacitated but mentally alert individuals to ambulate with little assistance from caregivers.

## 4.0 CONCLUSION

In this work we have considered all the biometric variables necessary for analysis, design and fabrication of cost effective, energy efficient and ergonomically friendly electronic driven wheelchair that runs on paired 12V DC power supply energized by solar system. This is a preliminary study into the alleviation of sufferings of disabled Africans. Efforts are ongoing to perfect the wheel-control system in the EDW to enable both the multidimensional attributes and the EEG smart module of the product. It is hoped that when completed, this work contributes to improving the welfare of the disabled in our society who currently do not have a wheelchair navigation aid for diverse reasons hence relying absolutely on human assistants to move about.

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